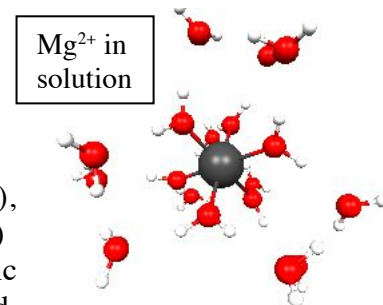


1. Introduction to solid Earth materials: minerals
 - a. Most abundant minerals contain the most abundant elements (Si, O) – silicates dominate
 - i. Characteristic silicate “building block”: $[\text{SiO}_4]^{4-}$ tetrahedron
 - ii. Silicates are classified according to how O atoms are shared between adjacent silicate tetrahedral
 1. isolated: $(\text{Mg,Fe})_2\text{SiO}_4$ olivine
 2. chains: $(\text{Ca,Mg,Fe})\text{SiO}_3$ pyroxene
 3. double-chains: $(\text{Ca,Mg,Fe,Al})_7(\text{Al,Si})_8\text{O}_{22}(\text{OH})_2$ amphibole
 4. sheets: $\text{KMg}_3(\text{AlSi}_3)\text{O}_{10}(\text{OH})_2$ mica (biotite)
 $\text{Al}_4\text{Si}_4\text{O}_{10}(\text{OH})_8$ clay (kaolinite)
 5. 3d-network: SiO_2 quartz,
 $(\text{Na,Ca,K})\text{Al}(\text{Al,Si})_3\text{O}_8$ feldspar
 - b. Other mineral types: salts (ionic bonding), oxides (+3,+4 cations), phosphates
2. Igneous rocks formed by melting in the Earth’s interior (usually within 100 km of the surface) are generally not in chemical equilibrium with the atmosphere or hydrosphere. The cycle of reaction between these reservoirs leads to weathering and the development of soils.
 - a. Melts tend to be richer in SiO_2 , Al_2O_3 , Na_2O , K_2O , and volatiles, poorer in MgO and FeO than the parent rock.
 - i. Hardest to melt/first to xtallize: $(\text{Mg,Fe})_2\text{SiO}_4$ olivine, $(\text{Mg,Fe})\text{SiO}_3$ pyroxene, $(\text{Ca,Mg,Fe})_7\text{Si}_8\text{O}_{22}(\text{OH})_2$ amphibole, $(\text{Ca,Na})\text{Si}_3\text{O}_8$ feldspar.
 - ii. Easiest to melt/last to xtallize: SiO_2 Quartz (in mixture), $\text{KAl}_3\text{Si}_3\text{O}_{10}$ white mica, KAlSi_3O_8 feldspar, $\text{NaAlSi}_3\text{O}_8$ feldspar.
 - b. Susceptibility to weathering greatest for earliest xtallizers.
 - c. Rock weathering is enhanced by natural acids present in groundwater.
 $\text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ + \text{HCO}_3^- \leftrightarrow 2\text{H}^+ + \text{CO}_3^{2-}$
 $\text{SO}_2 + 1/2\text{O}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{SO}_4 \leftrightarrow \text{H}^+ + \text{HSO}_4^- \leftrightarrow 2\text{H}^+ + \text{SO}_4^{2-}$
 - d. Acid/rock reaction puts some elements in solution, others remain in re-formed minerals.
 - e. Residue from weathering: Bedrock \rightarrow regolith \rightarrow soil. In moist environments progressive loss of most soluble elements.

3. Chemistry of solution/weathering:
 - a. In general, elements that form strongly basic hydroxides are most easily transported by acidic water – Na (NaOH), K (KOH), Mg ($\text{Mg}[\text{OH}]_2$), Ca ($\text{Ca}[\text{OH}]_2$)
 - b. Elements that form weakly basic or acidic hydroxides aren’t transported easily, tend



to stay behind & form new minerals – Al (Al[OH]₃), Fe (Fe(OH)₃), Si (Si[OH]₄), Ti (TiO₂), Zr (ZrO₂).

- c. Another way to think about it: most +1, +2, +6 cations are mobile, most +3, +4 cations are immobile (C⁴⁺ is an exception). All anions are mobile. O²⁻, OH⁻ added/subtracted as needed by water itself.
 - d. Carbonic acid usually most important in moist environments with well-developed soils, often strongly concentrated in soil (100x atmosphere!) by plants/bacterial respiration of organic material.
4. Typical weathering reaction: $\text{Mg}_2\text{SiO}_4 + 4\text{H}_2\text{CO}_3 \rightarrow 2\text{Mg}^{2+} + \text{H}_4\text{SiO}_4$ (or SiO₂) + 4HCO₃⁻ neutralizes carbonic acid
- a. Rapidly weathering soils generally have near-neutral pH.
 - b. Once “basic” cations leached out, soil water pH decreases.
 - c. Acid soil water can start to mobilize Si.
 - i. Ore from highly weathered soil?
5. Organic acids (citric, fulvic) also can enhance weathering. May be exploited by organisms to enhance availability of vital nutrients. Large organic acids can CHELATE otherwise weakly soluble or insoluble ions like Fe³⁺:

CHELATE – attach (usually reversibly) to an ion with multiple bonds (picture of synthetic EDTA).

a.

